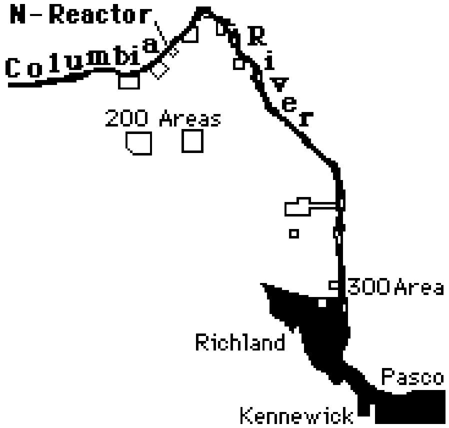

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Hanford Reach Project

SUMMER 1986 DATA REPORT

Data Report No. 2

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Summary

HRP sampled Columbia River Spring #8-12 near the 1301N/1325N cooling water disposal trenches. Nitrate concentration in the spring water and environmental radiation there were far above normal suggesting a possible leak of undecayed N-Reactor and fuel cooling water into the river. Such a leak would be dominated by short-lived radionuclides.

Based on these observations, HRP reviewed the radionuclide monitoring and reporting process for N-Springs, of which Spring #8-12 is part. United Nuclear (UNC) reports releases to the river at N-Springs. Battelle Pacific Northwest Laboratory (PNL) attributes almost all of Hanford's radiological impact to ^{90}Sr released from these springs. HRP discovered that the radionuclide release from N-Springs is consistently under-reported by a factor of 2.4. The PNL monitoring program does not detect this discrepancy. PNL monitoring is particularly insensitive to short-lived radionuclides which would dominate a waste water leak into the river.

A large waste leak into the river could exceed Washington State drinking water guidelines for gross beta activity (50 pCi/L) at the Richland water intake. There is no assurance that PNL would detect such a leak. Even if PNL did detect a violation of drinking water guidelines, that detection would occur days or weeks after the event. There would be little incentive to inform the public that it had drunk something it might not have wanted to.

Although no adverse public health effect is demonstrated, neither does PNL monitoring document continuous Columbia River water quality within drinking water guidelines downstream of Hanford. We recommend a real-time, gross beta counter/recorder with an alarm set at about 30 pCi/L be installed at the Richland pumping station and an appropriate contingency plan be established.

The channel study described in our Spring 1986 Data Report is further refined. The best estimate of average channel flow at River Mile (RM) 28 is 10 cubic feet per second (cfs) as compared to the raw measured value of 6.3 cfs.

Introduction

The results and implications of a reconnaissance study of the Upper Hanford Reach between 11 and 13 July 1986 are reported.

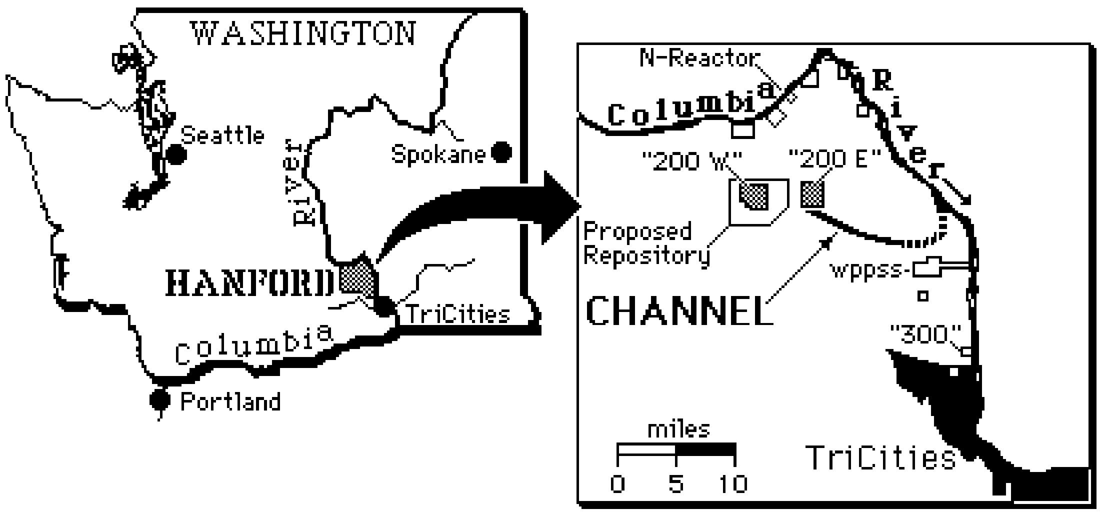
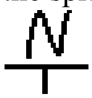


Fig. 1. Location Map

Seepage of N-Reactor coolant from onshore trenches to the river is the most important groundwater feature of the Upper Reach. PNL calculates that the strontium-90 (^{90}Sr) in this seep accounts for almost all of Hanford's radiological impact. This data report evaluates contaminated spring water entering the Columbia River near the N-Reactor discharge trenches. The emphasis is on the safety of Columbia River water for downstream uses, above McNary Dam.

Observations

At Spring #8-12 [see PNL-5289, p. A.3 for location], *gurgling* was heard. The investigators moved recently applied gravel and boulders at the shoreline to sample spring water as it entered the river. They marked a large boulder next to the spring



in orange to allow exact location. The width of the audible spring was about 5 feet. Nitrate concentration of this water was measured to be 15 ppm-N (66 ppm-nitrate) at 11:25 on 12 July 1986.

Radiation levels were measured with a Monitor 4™ meter [Solar Electronics International, calibrated on ^{137}Cs]. Levels were elevated above 0.02 mR/h only at Spring #8-12 where the two-minute average reading was 0.08 mR/h.

N-Springs flow

Spring #8-12 is part of "N-Springs" which discharge water originating at the 1301N/1325N Trenches. Let us consider the flow of water coming from those springs. The trenches receive a reported volume of 4.2 cfs (=$3.8x10^9$ L/year) of waste water from N-Reactor operations [UNI-3284, UNC nuclear industries reactor and fuels production facilities 1984 effluent release report, Table 3.1.3, 1985]. UNC measures concentrations of radionuclides in the discharge to the trenches and near N-Springs, calculates the implied releases in curies (Ci), and reports the results of these calculations, which PNL uses to estimate Hanfords health and environmental impact. PNL estimates that almost all of Hanford's impact is due to the release of ^{90}Sr from N-Springs into the Columbia River. This large impact warrants our review of the flow estimates which determine the impact.

UNC measures N-Reactor average annual concentration of 28 radionuclides in the discharge streams to the trenches and an average concentrations in N-Springs which discharge to the river. The product of annual water volume and average radionuclide concentration is total annual release of each radionuclide listed in UNC's Table 3.1.1. The tritium, strontium, and iodine data are reproduced in Table 1, below.

Table1. REPORTED ACTIVITY DISCHARGED

To 1301N/1325N Trenches

Nuclide	Release (Ci)	Conc.(Ci/L)	Flow (L)
^{3}H	140	$3.7x10^{-8}$	$3.8x10^{9}$
^{89}Sr	490	$1.3x10^{-7}$	$3.8x10^{9}$
^{90}Sr	310	$8.2x10^{-8}$	$3.8x10^{9}$

^{131}I	400	1.0×10^{-7}	4.0×10^{9}
. . .			
τ<48 hr.*	22,000	5.7×10^{-6}	3.9×10^{9}

To river via N-Springs

Nuclide	Release (Ci)	Conc.(Ci/L)	Flow (L)
^{3}H	set=140	2.9×10^{-8}	4.8×10^{9}
^{89}Sr	0.91	4.5×10^{-10}	2.0×10^{9}
^{90}Sr	7.0	3.5×10^{-9}	2.0×10^{9}
^{131}I	3.6	1.8×10^{-9}	2.0×10^{9}
. . .			
τ<48 hr.*	--	--	--

*Unspecified radionuclides with half-lives < 48 hours.

The reported release (in Ci) divided by the reported concentration (in Ci/L) gives the flow (in L) as calculated in the right column for both the discharge to the trenches and the N-Springs. The calculated flow to the trenches (3.8×10^{9}L) agrees with UNC's report. UNC also reports the flow to N-Springs to be 2.0×10^{9}L which agrees with all calculations except for ^{3}H. In order to release 140 Ci of ^{3}H from N-Springs, 4.8×10^{9}L of water must be discharged.

UNC noted that essentially all ^{3}H which is discharged to the trenches must enter the river at N-Springs. To carry 140 Ci of ^{3}H at an average concentration of 2.9×10^{-8} Ci/L to the river, 4.8×10^{9}L of water is required. But ^{3}H does not separate from the water which carries it. Thus, effective flow from N-Springs is 4.8×10^{9}L and not 2.0×10^{9}L. UNC has consistently under-reported its discharges to the river by a factor of

2.4

That is, UNC's 1984 release of ^{90}Sr to the river was about 17 Ci rather than the reported 7 Ci.

If we assume that UNC's estimated release from N-Springs was correct in 1974 and was the calculated 17 Ci in 1984, the calculated average curve is the dotted line connecting these points in Fig. 2, below.

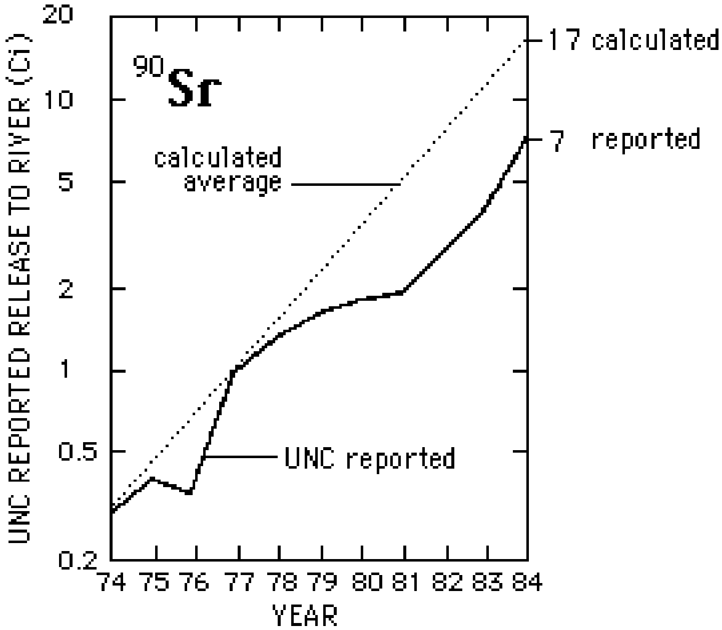


Fig. 2. ENVIRONMENTAL IMPACT OF HANFORD

The solid line in Fig. 2 is UNC's reported release. Comparison of these two lines suggests that UNC began to under-report N-Springs release about 1978.

PNL monitoring

Curiously, this consistent under-reporting by a factor of 2.4 of Hanford's most important radiological release was not detected by PNL's monitoring program. That program has four tiers of sampling:

- waste water entering groundwater from the trenches
- N-Springs discharge [see Fig. 2.1, UNI-3760]
- Richland water intake
- biota consuming Columbia River water

Yet those samples do not even measure UNC's actual releases from N-Springs to the river [PNL-5817, Table 12], much less detect the under-reporting.

Let us now consider the relation between the observed Spring #8-12 flow and PNL's monitoring system. To evaluate that relation, we must have some idea of the makeup of Spring #8-12 water.

Two-thirds - 26,000 Ci - of the total annual release to the trenches is reported as unspecified radionuclides with halflife less than 48 hours [Table 1]. None of these short-lived, unspecified radionuclides are reported by UNC to enter the river. Obviously, UNC would not report these radionuclides entering the river if UNC did not sample the pathway by which they arrived at N-Springs.

One possible, high-speed pathway is a catastrophic failure of the soils between the trenches and the river. The exponentially growing release of ^{90}Sr to the river shown in Fig. 2 hints at a possible breakdown of soil resistance to ^{90}Sr migration.

Another possible pathway is a drain pipe leak. On 29 April 1985, UNC personnel discovered such a leak in a one-foot drain pipe from N-Reactor, between the reactor building and the river [Unusual Occurrence Report No. UNC-85-11]. That leak which was not close to Spring #8-12 was attributed to external corrosion and was repaired.

With these two possible explanations for the presence of undecayed waste water at Spring #8-12, we may inquire of the capability of PNL's monitoring system to detect a major intrusion of short-lived radionuclides in Columbia River water downstream of Hanford.

Inasmuch as Richland is about 7 hours downstream of Spring #8-12, and typical time between the Richland Pumping Station and the consumer is about 1.5 to 2 hours [personal communication, John Harrington, Water Division Supervisor, 17 July 1986], the total decay time between Spring #8-12 and the Richland consumer is only about 9 hours.

Unfortunately, UNC does not identify the radionuclides which dominate the 26,000 Ci of short-lived contaminants which are discharged to the trench. Lacking this identification, we reviewed the particulate airborne emissions from 100N Area to identify candidates from N-Reactor operation [UNI-3880, Table 2.2.1]. The largest airborne release is ^{76}As, an energetic (3 MeV) beta emitter with a half-life of 26 hours.

Let ^{76}As represent the short-lived radionuclides which would enter the river from a major leak of trench water. Neglecting sedimentation and filtration, 79% of discharged ^{76}As would enter Richland drinking water. A major waste water leak of half of trench water would then add about 100 pCi/L of short-lived beta activity to Richland water, twice the screening level for gross beta.

PNL downstream samplers have a minimum sampling period of two weeks which is thirteen ^{76}As half-lives. After two weeks, only one ^{76}As atom in 7000 would remain to be counted, and PNL does not analyze for ^{76}As or its stable daughter ^{76}Se anyway. After two weeks, the short-lived gross beta would be 0.01 pCi/L which is not detectable in typical Columbia River beta activity of 1 pCi/L [PNL-5817, Table A.58]. That is, a simple introduction of 100 pCi/L of short-lived radionuclides into the Columbia River would not approach PNL detection limits.

No real leak from N-Reactor operations would be pure short-lived radionuclides. Long-lived nuclides would also be discharged. As a final consideration of PNL's downstream monitoring, we may examine the record for interesting occurrences.

Through 1983, PNL collected cumulative samples of Richland Raw Water over one-month periods and tested those monthly average samples for gross beta. The last year for which PNL reports, the maximum monthly activity was 11±5.5 pCi/L [PNL-0538, Table 7]. Because of PNL's delayed analysis, that reported activity could not have included short-lived radionuclides. PNL's response to this occurrence was to note *a possible Hanford influence* [p. 13] and to discontinue delayed measuring of gross beta in Richland water. Clearly by the time PNL's gross beta analyses were completed, weeks after the occurrence, there was no point to informing the public that it had drunk something it might not have wanted to.

If at the present moment a major leak of radionuclides into the river at N-Reactor were to occur, those nuclides would enter Richland drinking water about 9 hours from now. Unless UNC detected and reported this leak, PNL and Washington State would become aware of the problem a few weeks from now.

Recommendations

To assure safety of all downstream river water uses above McNary Dam, we recommend -

- a real-time gross beta counter having a sample period of no more than one hour be installed at the Richland water intake. This counter automatically provide a record which is published.
- an operable backup counter be in place.
- an automatic alarm on the counter be set at 30 pCi/L to alert the Water Division operator.
- an emergency response plan with an implementation time of no more than one hour be in operation.
- N-Springs discharge into the Columbia River be monitored independently of the N-Reactor operator.

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DOE laboratory analyses for RM 28 channel study

Eight Columbia River water samples from the vicinity of RM 28 were submitted to DOE for analysis of nitrate and tritium in connection with the HRP channel study of April 1986. DOE analyses are compared to previously listed HRP measurements, in Table 2, below.

Table 2. DOE Special River Sample Data

#	Time	Source Location	Current |Depth	HRP-NO3	DOE-NO3	Tritium	Temp
39	0845-20	SS 30' US of DS section	- | -	4.7	4.5	8.9x10^{4}	15.4
40	0915-20	SS 100' US of US section	- | -	1.24	0.93	3.9x10^{4}	14.3
41	1030-20	Mid R between sections	- | -	0.18	0.020*	1.3x10^{2}	7.9
42	1415-20	UW 40' OS, 109' US of DS sec.	- | 6	4.7	3.6	8.6x10^{4}	14.0
43	1430-20	R 100' OS on DS section	2.20 | 8.6	0.20	0.043*	7.4x10^{2}	9.5
44	0854-21	R 276' OS on DS section	3.34 | 12.5	0.172	0.047	1.0x10^{2}	8.0
45	0910-21	R 148' OS on DS section	2.75 | 11.5	0.160	0.043*	1.7x10^{2}	8.1
46	1110-21	SS RM 28.2 (Spring 28-2?)	- | -	5.62	4.97	1.0x10^{5}	17.5
47	1300-21	repeat Sample #39, diluted 9:1	- | -	6.4	4.97	1.5x10^{5}	18.8

* Below minimum detection concentration of 0.045 ppm

#	Sample number. PNL numbers are the listed number prefixed by "86-". For example, "39" is PNL No. "86-39".
Time	Local 24-hour clock time of sample collection followed by a hyphen and the day of April 1986. For example, "0845-20" is 8:45 AM, 20 April 1986. Value reported by HRP.
Source Location	Abbreviations are as follows: "SS" = shoreline spring; "UW" = underwater spring; "R" = river; "US" = upstream; "DS" = downstream; "OS" = offshore. Reference data are provided in our Spring 1986 Data Report. Reported by HRP.
Current | Depth	Current is river current, downstream in all cases, in feet/second at one-foot depth. Depth is station depth in feet. Reported by HRP.
HRP-NO3	Nitrate as measured by HRP at the time of sampling with Orion ion-selective electrode calibrated for ppm-N by serial dilution of Orion standard to 0.5 and 5.0 ppm-N. Reported by HRP.
DOE-NO3	Data provided by DOE are for nitrate-as nitrate. HRP divided the DOE data by 4.43 to yield values of nitrate-as

	nitrogen, comparable to HRP data, in Table 3. Original DOE data are nitrate-as nitrate. To obtain nitrate-as nitrate, multiply value by 4.43.
Tritium	pCi/L. Reported by DOE.
Temp	°C. Direct readout of Orion ISE, uncalibrated. Reported by HRP.

The DOE analyses are part of the quality assessment of HRP field work and relate the channel theory to historical samples of Spring #28-2 water.

<u>River Height at RM 28 Channel</u>

River level is routinely measured by USGS below Priest Rapids Dam. These data, lagged by 6.0 hours and set at an arbitrary reference level, are compared to HRP observations of staff height at RM 28 in March 1986 in Fig. 3, below. Priest Rapids data are open squares; RM 28 observations are solid circles.

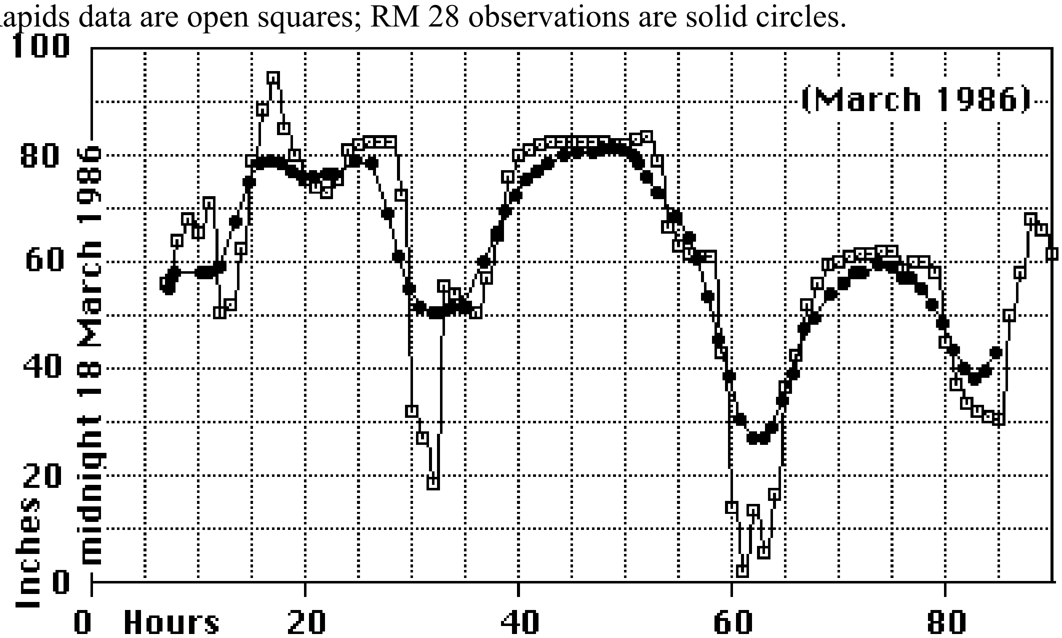

Fig. 3. COMPARISON OF RIVER LEVELS AT PRIEST RAPIDS AND RM 28

The height fluctuations at the dam appear to be somewhat smoothed, particularly at low river levels. In other regards, the fit appears reasonable.

Employing this same 6.0 hour lag from Priest Rapids and this same arbitrary reference level, the river level at RM 28 during the channel flow study in April 1986 is plotted below, using both Priest Rapids and HRP observational data as in Fig. 3:

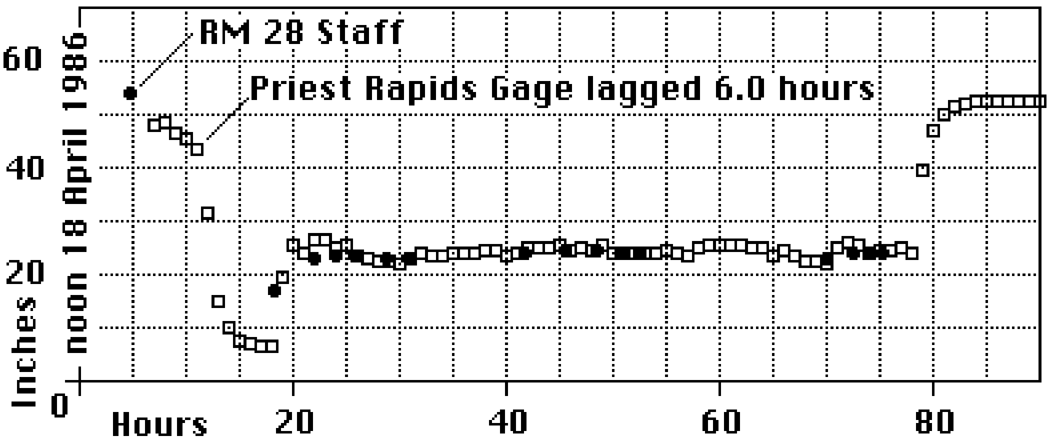

Fig. 4. RIVER LEVELS DURING APRIL CHANNEL STUDY

This confirms a nearly constant river height throughout the study. Figure 4 replaces Fig. 8 of the Spring 1986 Data Report; wherein, river heights were inverted.

QA/QC : **Channel flow errors**

This section refines the error analysis of the channel flow calculation begun in the last data report.

1. Lateral spill from channel before discharge • Near the 200 Areas, the channel theory posits that the channel collects water from most nearby sources; that is, the channel has a lower watertable elevation than nearby areas. As the channel approaches the Columbia River from the south, the water table gradient steepens, and the channel is presumed to spill. The fraction of flow which is spilled could be measured by hydrographic sections in the river between RM 28 and the cairn at RM 28.5. Those sections would require careful placement because of irregular river flow near RM 28.5.

Until data are obtained with additional sections, HRP suggests +30% for this spillage, based on informal, unreported nitrate measurements.

2. Lateral mixing off section ends • The Hanford Reach of the Columbia River is free flowing, with typical flow speeds of 4-6 mph. A visual feature of this flow is the presence of major gyres, or*whirlpools.*

Very simple scaling arguments suggested that such a flow could mix much of the channel discharge offshore beyond the end of the downstream section. (This loss of channel water results in an *underestimate* of channel flow rate.) At the same time, extending the downstream section farther offshore is not useful for a study based on nitrate concentrations. The problem is that the maximum measured nitrate concentration in the channel is about 5 ppm-N; whereas, the detection limit is about 0.002 ppm-N. That is, field nitrate methods only allow detection of channel water diluted about 2000-to-one.

Tritium methods allow detection of channel water at greater dilutions. The maximum measured channel concentration of ^{3}H [Table 2] was 150,000 pCi/L; whereas, the low level detection limit is about 10 pCi/L. That is, tritium methods allow detection of channel water diluted about 15,000-to-one. Since channel water is less diluted than this by the entire river, ^{3}H sections can be practically extended across the entire river. PNL upstream-downstream measurements of ^{3}H represent a simple case of such sections. The problem with ^{3}H methods is the high cost of laboratory analyses near background levels.

HRP elected to perform the much cheaper nitrate study with modest checks using tritium. In particular, two tritium stations were added to the downstream section for the fourth measurement set. These two additional stations are identified in Fig. 5, below, by the open squares (±). Sample #86-47 provided a channel-water tritium/nitrate ratio of

23,400 pCi/L-ppm-N

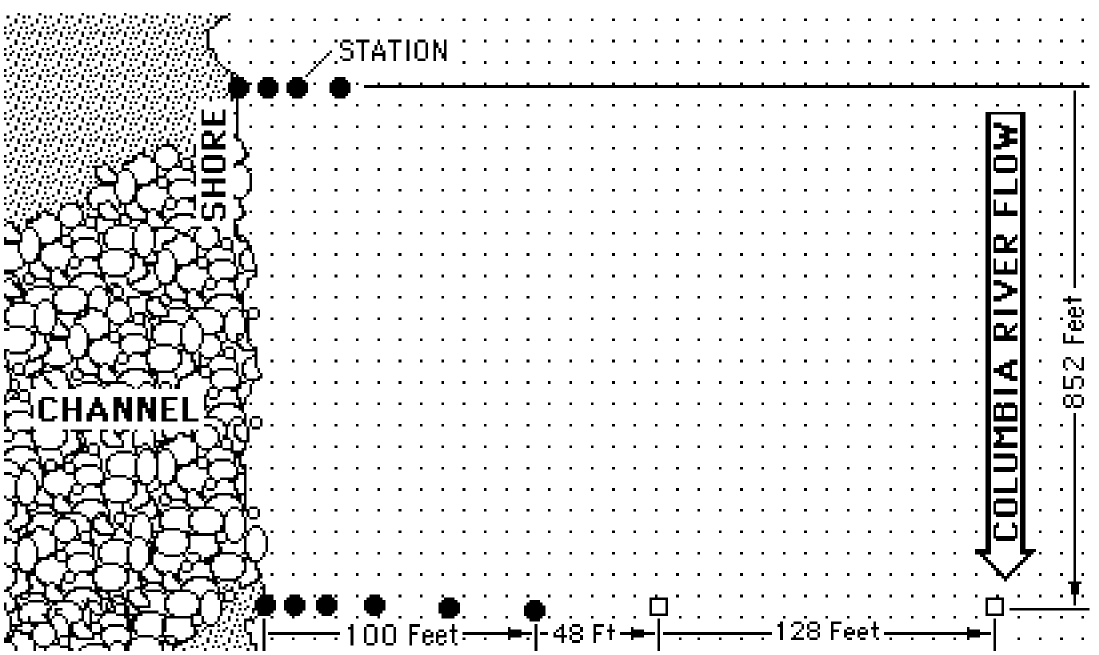

Fig. 5. EXTENDED DOWNSTREAM SECTION

Background tritium was taken from midstream Sample #86-41 to be 130 pCi/L. Any tritium concentrations less than background were assigned the value of background. Using the procedure described in the Spring 1986 Data Report, the calculated channel-water flow past the downstream section increased from 6.19 cfs to 7.39 cfs, a 19% increase. Profiles of that downstream nitrate section are shown in Fig. 6 for the five measurements, along with best exponential curve fits.

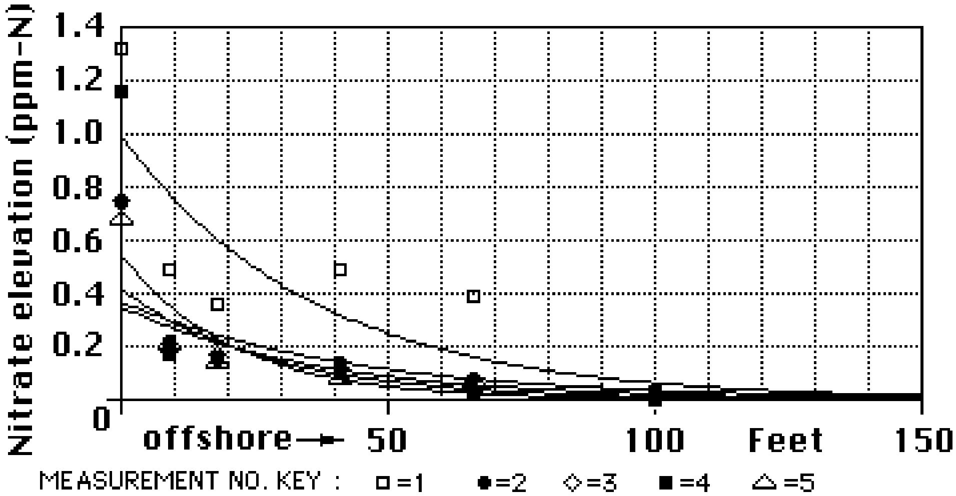

Fig. 6. DOWNSTREAM NITRATE PROFILES

The upstream nitrate section was blunter, as seen in Fig. 7, to the same scale, below.

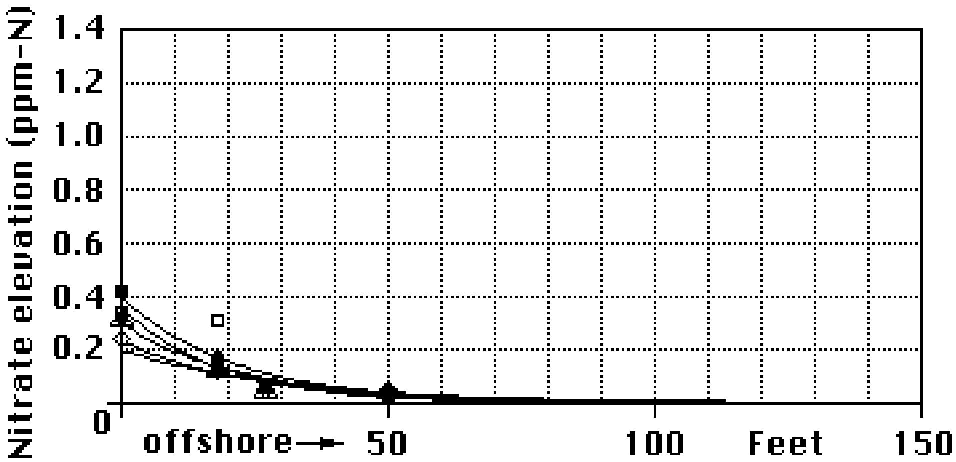

Fig. 7. UPSTREAM NITRATE PROFILES

Inasmuch as the upstream section subtracted 0.62 cfs from the flow based on nitrate, with the blunter upstream profile we may conservatively estimate that the upstream section also allowed 19% of nitrate-contaminated channel-water to pass the offshore end of the section. That is, we estimate the equivalently extended upstream section to pass about 0.74 cfs of channel water.

Our best estimate of channel water flow entering the river between the sections during Measurement No. 4 is then 7.39 - 0.74 cfs = 6.65 cfs, which is 19% greater than the estimate based only on nitrate stations. That is, we estimate that 19% of channel water entering between the nitrate sections mixes offshore of the downstream section.

3. Short Duration of Study • M. Graham questions whether equilibrium has been reached, citing USGS data that river bank discharge requires half a year after spring-summer high water near RM 28 [informal communication, 29 July

1986 Meeting]. That is, the flow may be driven by river bank storage even though other areas of shoreline springs had ceased to flow.

The channel flow measurement was conducted when river levels had not been much above normal for long before 19-21 April 1986. The river had only been high between 30 March and 6 April (to 190,000 cfs) and between 13 and 18 April (to 197,000 cfs).

HRP agrees that river water had not been flushed out of the channel at the time of the study, but the pressure-driven flow only decreased from 7.11 cfs to 7.01 cfs between study hours 23 and 47, as shown in Fig. 8.

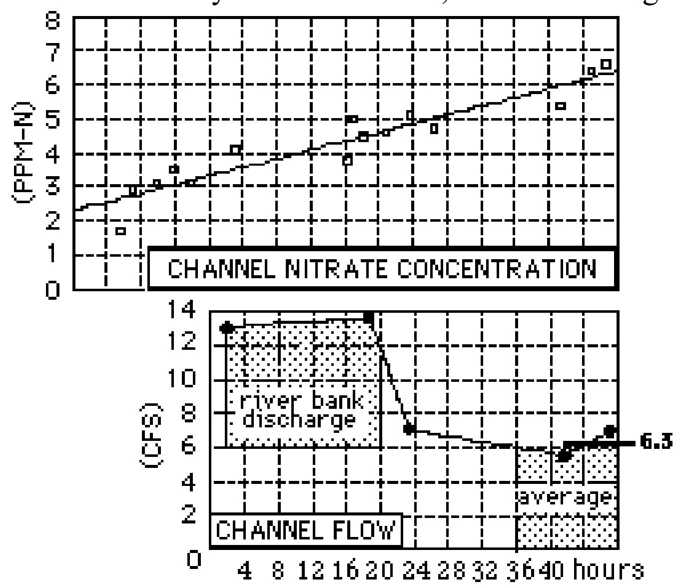

Fig. 8. RIVER BANK DISCHARGE

By this comparison, we see that river bank discharge ceased abruptly after Measurement No. 2. Five hours later, measured flow was halved. After another 24 hours and river bank discharge was not apparent away from the study area, channel discharge had only diminished another 1%. Still, a study of greater duration would increase confidence that equilibrium was reached. For this analysis, an additional 1% bias is assumed.

4. Study coarseness • Several errors are introduced by the coarseness of the study. These errors involve considerations of the duration of each measurement period, the difference between Spring S1 nitrate and mean channel nitrate, location of nitrate and current measurements in the water column, spacing of stations, and random errors involving individual measurements. These errors generally appear trivial to moderately conservative, underestimating channel flow rate.

Study design incorporated features to minimize these errors or render them conservative. For example, instantaneous nitrate values of Spring S1 were used to represent channel water vs. linear fit values as shown at the top of Fig. 8, above. The instantaneous values respond to short-time variations in the amount of river-water dilution of channel water. Meanwhile, Spring S1 is upstream of almost all of the channel discharge since it is onshore. Since Spring S1 nitrate concentrations were rising nearly linearly during the study, the actual discharge from the river bed must have been of lower nitrate concentration. Thus, Spring S1 overestimates the instantaneous discharged nitrate concentration, which is a conservative error.

Because calculations of flow were particularly sensitive to the background value of nitrate, special care was taken to obtain repeatable, temperature-stabilized midriver values. Typical repeatability was better than ±0.001 ppm with background near 0.18 ppm-N. This precision exceeds rated laboratory accuracy of 1%; however, the flow calculation is more sensitive to precision than accuracy.

5. Nonlinearity at low nitrate concentrations • Ion selective electrodes are nonlinear at nitrate values below 1 ppm-N. This nonlinearity reduces instrument sensitivity to low levels of nitrate. At river levels of nitrate concentration (0.2 ppm-N), the reduced sensitivity is about 5%.

Ion selective electrodes (ISE) are sensitive to ions other than the ions which they are designed to measure. The nitrate electrode is particularly sensitive to ClO_4^-, I^-, ClO_3^-, CN^-, Br^-, and NO_2^- . The conflict between HRP background nitrate data and DOE data is attributed to such interference. The first order effect of this interference is to add a blank to background nitrate. This has no effect on the channel flow calculation. The second order effect is to scale all ISE values downward by the ratio of HRP Spring S1 values to DOE values in Table 4 - about 20%. This also has no effect on the calculated flow. The exact nature of the hypothetical interference could have third order effects which are unknown and the subject of continuing study.

Summary of errors • The errors which have been quantified have the following effects:

Table 5. ESTIMATED ERRORS IN CHANNEL CALCULATION

Error Code: C=conservative, A=anticonservative, N=Neutral or trivial

Error class	**Error**	**Est.%**
1. Lateral spill from channel before discharge	- C	+30
2. Lateral mixing off section ends	- C	+19
3. Short duration of study	- A	-1
4. Study coarseness	- N	0
5. Nonlinearity at low nitrate concentrations	- C	+5
Multiplicative Total		**+61**

That is, our best estimate of total channel discharge near RM 28 is 1.61 • 6.3 cfs = **10 cfs**

Conceptual basis for HRP approach

This problem of model calibration confounded attempts to build computer groundwater flow models for Hanford in the late 1960's and early 1970's. Eventually, a Transmissivity Iterative Routine was developed which was reasonably well behaved. This approach allows fine-scale high-conductivity flow paths to escape both the model and field verification based on well data.

The hydrographic approach used by HRP locates major stream tube outlets from Hanford by the elevation of a specific ionic concentration in river water, readily observable during downstream transects. Then the discharge is measured between hydrographic sections with river dilution allowing a simple flow calculation.

From the modeling standpoint, two properly selected hydrographic sections define a stream tube of interest. Defined in this manner, the stream tube is represented by a one-dimensional band which may be approximated by a single element, as sketched in Fig. 9, below.

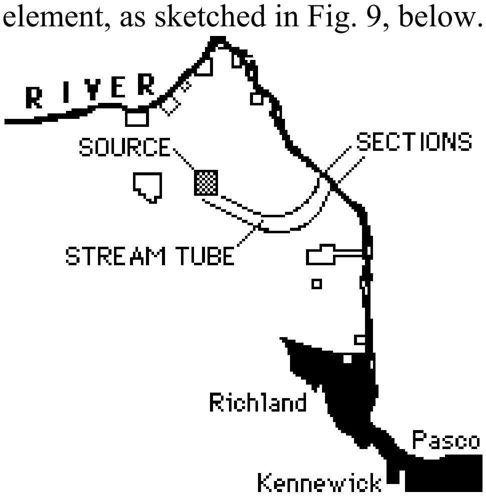

Fig. 9. STREAM ELEMENT MODEL

Such a model is specified relatively easily, cheaply, and accurately.

As pathway identification progresses at a given site, an array of rapid flow pathway types is identified. Such an array is suitable for statistical analyses to predict the likely, fastest pathway from a proposed source location at the site. Since this approach is based on fastest pathways rather than typical pathways, the required statistics are close to model mean.

Acknowledgements

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